PATENT SPECIFICATION

(11) 1 327 944

DRAWINGS ATTACHED

1 327 944

(21) Application No. 52298/70 (22) Filed 3 Nov. 1970
(31) Convention Application No. 873 313
(32) Filed 3 Nov. 1969 in
(33) United States of America (US)
(44) Complete Specification published 22 Aug. 1973
(51) International Classification F17C 3/02
(52) Index at acceptance
F4H G13
F4P 1B4 1B6

(72) Inventor JAMES R. DEHAAN

(19)

(54) METHOD AND APPARATUS FOR COOLING A CRYOGENIC STORAGE CONTAINER

(71) We, CRYOGENIC ENGINEERING COMPANY, a corporation organised and existing under the laws of the State of Colorado, United States of America, of 4955 Bannock Street, Denver, Colorado 80216, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

Many systems have been devised for limiting the heat that is permitted to leak into cryogenic storage vessels. Several such systems relate to structures for recovering some of the refrigeration value from the gases which boil out of the vessel's interior. Devices of this type are described in United States Patents 3,133,422 and 3,341,052. The structures described therein include a plurality of highly conductive shields in the vessel's vacuum space. The shields are affixed to a heat absorbing fluid conduit so that refrigeration from boil-off gases passing through the conduit is first given up to the conduit and then passed on to the shields so as to cool the vacuum space. It is an object of this invention to provide a method and apparatus for further increasing the amount of boil-off gas refrigeration that is transmitted to the vessel's vacuum space.

A drawback of previous devices is that relatively large numbers of shields have been required, thereby resulting in structural complexity and expense, particularly in the case where fins have been included in the interior portions of the conduit. Consequently, another object of this invention is to provide a method and apparatus for maintaining a high rate of refrigeration transfer from the vessel's boil-off gas to the vessel's vacuum space while at the same time reducing the number of shields that are required.

The use of fins on the interior portions of the vessel's conduits has been limited to use by either relatively large conduits or has required impractical and complex manufacturing procedures. Hence, it is another object of this invention to provide a structure which has a very high rate of transfer of boil-off gas refrigeration to the vessel's vacuum space even though the particular conduit may be of small diameter.

In accordance with the present invention there is provided a double-walled cryogenic storage vessel having a cold storage container wall an outer wall separated therefrom by a vacuum space through which extends a conduit of low thermal conductivity communicating with the cold storage container and providing a channel for the flow of boil-off gas, and a highly thermally conductive radiation shield extending into the vacuum space from an intermediate portion of the said conduit, the said intermediate portion of the conduit being at least one inch long and being of increased thermal conductivity, and the said channel being restricted at the said intermediate portion to increase the velocity of gas flowing therethrough. The invention also provides a method of conserving the refrigeration value of the boil-off gas from a double-walled cryogenic storage vessel having a cold storage container wall separated from a warm outer wall by a vacuum space through which a low thermal conductivity conduit extends from said container wall to said outer wall, to provide a channel for the flow of said boil-off gas, a thermally highly conductive radiation shield extending into the vacuum space from an intermediate portion of the conduit, which method comprises increasing the thermal conductivity of the said intermediate portion of the conduit over at least one inch along the length of said conduit, directing

said boil-off gas through said channel, and restricting the channel at said intermediate portion of the conduit to increase the velocity of said gas as it flows through the restricted portion of said channel and thereby increase the transfer of cold from said boil-off gas to said selected portion of said conduit.

A selected portion of the conduit intermediate its ends is preferably surrounded by a high thermal conductivity collar which functions to provide a highly conductive zone of the surrounded tube. The collar should be at least one inch long so as to make at least that much of the conduit highly thermally conductive. In addition, the velocity of the boil-off gases is preferably increased in the portion of the conduit surrounded by the collar by means of a packing material. It has been found that this increase in velocity also increases the refrigeration that is transferred from the conduit's boil-off gas to the collar. It has also been found that results are still further increased if the packing is comprised of a fine fibrous low conductivity material such as terepthalic ester polymer fibers that are packed in the conduit for at least as much of its length as is surrounded by the collar. The radiation shield which extends through the vessel's vacuum space is attached to the collar so that the thusly transferred refrigeration is distributed through the vessel's vacuum space. In this respect, in order for the refrigeration to travel to the shield, the highly conductive collar should surround the conduit at an area that is colder than the shield would be if not connected to the collar.

Preferred embodiments of the invention are illustrated in the accompanying drawings, wherein the same reference numerals refer to the same parts throughout the various views. The drawings are not necessarily intended to be to scale, but rather are presented so as to illustrate the invention in clear form.

In the drawings:

FIG. 1 is a pictorial view of a dewar vessel of the type in which this invention finds particular utility;

FIG. 2 is a fragmentary sectional view taken along the arc 2—2 in FIG. 1;

FIG. 3 is an alternative embodiment of the invention which is particularly suited for use with relatively small conduits such as vent lines.

In FIG. 1 a conventional dewar vessel 10 has a neck portion 12 having an outlet tube 14 extending therefrom. The neck 12 is equipped with a flanged cap 16 having a relief valve 18 therein. This structure has been cut-away in FIG. 2 which illustrates the vessel 10 as having an outer shell 20 enclosing an inner container 22 for a cryogenic fluid, not shown. The space between the two walls 20 and 22 is evacuated to form an insulating vacuum space 24.

The vacuum jacket preferably contains one or another of a variety of bulk insulations materials. One of the more satisfactory types of bulk insulations is comprised of a plurality of radiation barriers 26 which are separated from each other by a suitable low conductive fibrous material 28. For purposes of simplicity, only a small portion of that type of insulation is illustrated in the drawings, but in practice the vacuum space 24 is usually substantially completely filled with such a laminated insulation. In this respect, a multi-layer insulation of this type is described in more detail in an article by Dr. Richard H. Kropschot of the National Bureau of Standards. This article appears in the March 1961 issue of Cryogenics, Vol. 1, No. 3, and is entitled "Multiple Layered Insulation for Cryogenic Application". A suitably opacified powder type of insulation can also be employed in the vacuum space. These matters, however, form no part of the instant invention and will not be further discussed.

The inner container 22 is supported from the outer shell 20 by means of a low thermally conductive neck tube or conduit 30 which is preferably made of a fiberglass reinforced epoxy resin or stainless steel and should have as thin a wall as possible, compatible with the strength required to support the inner container 22 and its contents. The neck tube 30 is surrounded by a collar 32 of a highly thermally conductive material such as aluminum, and is suitably affixed to the exterior of the neck 30 so as to insure good thermal contact therebetween. The collar 32 functions to increase the thermal conductivity of the portions of the neck tube 30 which it surrounds. In this respect, it has been found that the height of the collar (between lower surface 34 and upper surface 36) should be a minimum of one inch in order to provide a suitably wide area of the neck tube 30 having an increased thermal conductivity. Collars as high as four inches have also been found satisfactory, but it should be noted that the temperature differential between surfaces 34 and 36 of the collar is only a few degrees. Hence, the effective thermal length of the neck tube 30 is reduced. The overall length of the neck tube 30 should be proportionately increased, therefore, to maintain a sufficiently small transfer of heat from the vessel's surroundings, down the neck tube 30 to the inner container 22.

A highly thermally conductive shield 38 is affixed to the collar 32 so as to surround the inner container 22 within the vacuum space 24; and a second low thermal conductivity

tube 40 is located within the neck tube 30 to form an annular space 42 between the two tubes. The top of the inner tube 40 is covered by a cap 44 having a pressure relief member mounted therein. Hence, boil-off gases from the container 22 are forced to travel upwardly through the annular space 42 and out a vent hole 48 in the neck tube 30 so as to be exhausted through the outlet tube 14.

In the absence of its connection to the collar 32 the shield 38 would be at a given temperature depending upon its location between the outer and inner vessel walls 20 and 22. Consequently, in order for the boil-off gas refrigeration to be passed on to the shield, the collar 32 should surround an area of the outer conduit 30 that is at a temperature lower than that at which the shield 38 would be if not connected to the collar.

A fine fibrous low conductive packing material 50 is comprised of terepthalic ester polymers, one type of which is identified by the trademark "DACRON". Such fibers having diameters of greater than 10 microns, but less than 100 microns are placed in the annular space 42 adjacent the collar 32. In this respect, packing materials have also included metal wool, highly conductive screening, and a narrow metalic ribbon, but as will be described shortly, better results are obtained when the relatively non-conductive fibrous packing material is used. A packing material of either type functions to restrict the cross sectional area of the annular space 42 and increase the velocity of the boil-off gas as it passes the area of the collar 32. In addition, the fine fibrous fibers dampen certain heat producing vibrations which tend to occur otherwise. The packing material also causes an increase in the turbulence of the boil-off gas and in addition, in the case of the metallic packing, provides a path for the transfer of cold from the inner tube 40 to the outer tube 30. Whichever type of packing is used, the increased velocity of the boil-off gas causes an increase in the refrigeration that is transferred to the collar 32, the shield 38 and the vacuum space 24. Packing plugs have certainly been used in the past to restrict gas flow. Frequently, however, such plugs have caused problems because they have encouraged the formation of frozen air in the vessel's neck tube. The instant structure avoids the undesirable effects of this problem because in the event of such freezing the vessel's boil-off gases can still exit through the inner conduit 40 and the pressure relief valve 18.

The above described structure also provides substantial increase in the surface area to which the refrigeration value of the boil-off gas can be transferred. That is, the boil-off gases pass over all of the surfaces of the packing material as well as the inner and outer tube surfaces adjacent the packing material. Hence, the refrigeration value of the boil-off gas is transferred the collar 32 by both forced gas convection as the gas is forced through the annular space at a high velocity; and at least where metallic packing is employed by solid conduction from the inner tube 40, through the metallic packing material and through the portion of the neck 30 that is surrounded by the collar 32. In these respects, it should be noted that best results are obtained when the packing material extends along at least as much of the length of the annular space as is surrounded by the collar 32.

On occasion, the boil-off gas flows out of a dewar vessel at an excessively high rate. This occurs, for example, during filling or perhaps when the vessel is damaged and its vacuum is lost. For this additional reason, therefore, it has been found desirable to include the pressure relief valve in the central tube 40.

It has been found that the above described structure results in both a minimum tendency for heat to flow downwardly into the interior portions of the storage vessel while still permitting the transfer of a considerable amount of the boil-off gas refrigeration to be transferred to the vessel's vacuum space. Moreover, this is accomplished by the relatively simple structure of a collar 32 surrounding the low thermal conductivity neck tube 30 and the annular space between the inner and outer tubes having an increased flow velocity by means of a packing extending along at least as much of the annular space as is surrounded by the collar. This structure, therefore, eliminates the need for the large plurality of heat transfer shields that have previously been used. Hence, the structure of the invention reduces both the cost and complexity of the dewar's fabrication; and at the same time provides an increase in the vessel's overall insulation efficiency. Moreover, the vessel's efficiency is still further increased where a fine fibrous low conductive packing is employed.

The annular space 42 between the inner and outer tubes 40 and 30 is preferably about 1/16 to 1/8 inch wide and the height of the collar is preferably between about 1 to 4 inches for dewars having capacities of between 50 to 500 liters. The height of the collar 32 can be varied from this height range, but the effectiveness thereof is rapidly decreased when it is less than one inch in height; and a height of more than about four inches would sometimes result in an inconveniently long neck tube.

As noted above, in one preferred embodiment of the invention, the packing material was comprised of fibers of

terephthalic ester polymers of between about 10 and 100 microns in diameter This fine fibrous packing was placed in a low thermal conductivity conduit of a 50 liter dewar in the manner described above and the dewar was subjected to heat transfer tests to determine its boil off rate. In this respect, the vessel's loss rate was only 1.2% per day which is a substantial improvement over the heat loss that is expected for corresponding vessel's that lack the improvements of this invention. In fact, it is even a substantial improvement over an otherwise similar test dewar which used only a 5/8 inch copper screen packing within a 1 inch collar. That "copper screen dewar" had an indicated heat loss of 1.6% per day which itself is quite an improvement over corresponding but otherwise conventional dewars. But, the fine fiber packing embodiment represents a 25% improvement over even the improved results obtained by the "copper screen dewar." Hence, it will be appreciated by those skilled in the art that the invention provides admirable results even though they are obtained in a manner which is in many respects less complicated then the prior art.

It has also been found that additional shield and collar structures can be employed satisfactorily. In this event, however, the collar 32 corresponding to the colder of the two shields should be made shorter than the collar for the warmer shield. But in any case, for a given amount of boil-off gas refrigeration that is transferred into the vessel's vacuum space, the required number of shields 38 does not approach the number that have been required in the prior art devices which have not employed elements corresponding to collar 32 in combination with related restricted-flow portions such as that provided by the packing material 50 placed in the annular space 42 of the instant structure.

Thus far, the invention has been described in terms of a relatively large neck tube which is used to support the vessel's inner storage container. Frequently, however, small vent tubes extend from the vessel's inner container, and through the vacuum space to the outer wall. Although it might not be practical to install a separate tube inside of such a vent line, it is nevertheless practical to practice the invention's broader concepts. For example, with reference to FIG. 3, a vent line 60 extends from the vessel's inner wall 22 to its outer wall 20. In this respect, the vent tube 60 is illustrated as being straight, but conventionally, such tubes are bent several times for any number of reasons prior to the time that they emerge from the vessel's outer wall. The vent tube 60 is surrounded by a collar 62 corresponding to a collar 32 in the neck-tube embodiment of the invention. The collar 62 has a lower surface 64, an upper surface 66, and is connected to a shield 68 which extends throughout the vessel's vacuum space in the same manner as was described above.

The vent tube 60 is filled with a terepthalic ester polymer fiber packing material 70 in the cross section of the tube extending at least along the length bounded by the lower and upper surfaces 64 and 66 of the collar 62. In this manner, the packing material 70 functions to most efficiently increase both the velocity and turbulence of the boil-off gases through tube 60.

Both the increased velocity and the increased turbulence are effective to increase the rate of transfer of the refrigeration from the boil-off gas to the portion of the wall 60 that is surrounded by the collar 62. Hence, the amount of refrigeration that is permitted to pass from the collar 62 to the shield 68 is increased considerably over the amount of refrigeration that would be transferred in the absence of either the collar or the packing. Moreover, as in the case of the first embodiment, the above described structure eliminates the need for the previously required large number of shields while at the same time providing a low thermally conductive vent tube material so as to decrease the amount of heat flowing into the vessel through the walls of the vent tube 60 from the surrounding air to the inner container 22.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it should be noted that various changes in form and details may be made therein. For example, although the invention has been described in connection with a standard neck-type of dewar, it will be appreciated by those skilled in the art that the invention is equally applicable to the larger horizontal types of dewars, such as those that are sometimes mounted on mobile platforms. Similarly, the conduit can have the highly thermally conductive portion formed as a part thereof rather than as a collar; and part of the restricted portion of the conduit can be obtained by reducing its diameter at a selected section. Such modifications will be contemplated by those skilled in the art, however, and will not be described in more detail.

WHAT WE CLAIM IS:—

1. A double-walled cryogenic storage vessel having a cold storage container wall, an outer wall separated therefrom by a vacuum space through which extends a conduit of low thermal conductivity communicating with the cold storage container and providing a channel for the flow of boil-off gas, and a highly thermally

conductive radiation shield extending into the vacuum space from an intermediate portion of the said conduit, the said intermediate portion of the conduit being at least one inch long and being of increased thermal conductivity, and the said channel being restricted at the said intermediate portion to increase the velocity of gas flowing therethrough.

2. A vessel according to claim 1 wherein a collar of thermally highly conductive material is located in said vacuum space and surrounds the outer surface of the said intermediate portion of the first-mentioned conduit so as to be in heat transfer relationship with said outer surface for at least one inch along the length thereof, the collar having the radiation shield affixed thereto.

3. A vessel according to claim 2 wherein the channel is restricted at the said intermediate portion by restriction means extending along at least the same length as that for which said collar extends.

4. A vessel according to any one of claims 1 to 3 wherein the channel is restricted at the said intermediate portion by restriction means comprising a packing material in said channel in heat transfer relationship with the inner surface of the conduit.

5. A vessel according to claim 2, 3 or 4 wherein said restriction means has an effective thermal conductivity about equal to that of terephthalic ester polymer fibres.

6. A vessel according to claim 4 wherein said packing material comprises fibres having diameters of less than 100 microns.

7. A vessel according to claim 6 wherein said fibres comprise terephthalic ester polymer fibres.

8. A vessel according to claim 2 or to claim 2 together with any of claims 3 to 7 including at least a second thermally highly conductive collar located in said vacuum space and surrounding at least a second intermediate portion of the outer surface of the conduit so as to be in heat transfer relationship with said outer surface, the height of the collar closer to said storage container wall being less than the height of any collar further from said storage container wall.

9. A vessel according to claim 8 including a thermally highly conductive radiation shield affixed to each of said collars, each of said shields extending into said vacuum space.

10. A vessel according to claim 8 or 9 wherein the collar closer to the cold storage container is at least one inch long.

11. A vessel according to any of claims 1 to 10 including a second low thermal conductivity conduit located inside the first-mentioned conduit to form the channel therebetween, means being provided for preventing the flow of boil-off gas through the second conduit in normal operation.

12. A vessel according to claim 11 wherein the means for normally preventing gas flow through said second conduit is responsive to a pressure in said storage container greater than a predetermined value to allow said boil-off gas to pass through said second conduit so as to relieve said pressure.

13. A vessel according to claim 11 or 12 wherein said second conduit is spaced from said first conduit by no more than 1/8 inch.

14. A double-walled cryogenic storage vessel substantially as described herein with reference to Figs. 1 and 2 of the accompanying drawings.

15. A double-walled cryogenic storage vessel substantially as described herein with reference to Fig. 3 of the accompanying drawings.

16. A method of conserving the refrigeration value of the boil-off gas from a double-walled cryogenic storage vessel having a cold storage container wall separated from a warm outer wall by a vacuum space through which a low thermal conductivity conduit extends from said container wall to said outer wall, to provide a channel for the flow of said boil-off gas, a thermally highly conductive radiation shield extending into the vacuum space from an intermediate portion of the conduit, which method comprises increasing the thermal conductivity of the said intermediate portion of the conduit over at least one inch along the length of said conduit, directing said boil-off gas through said channel, and restricting the channel at said intermediate portion of the conduit to increase the velocity of said gas as it flows through the restricted portion of said channel and thereby increase the transfer of cold from said boil-off gas to said selected portion of said conduit.

17. A method according to claim 16 in which the channel at said intermediate portion is restricted along at least the same length as that for which the thermal conductivity is increased.

18. A method according to claim 16 or 17 which includes increasing the turbulence of said boil-off gas as it flows through the restricted portion of said conduit.

19. A method according to claim 18 wherein said turbulence is increased by directing said boil-off gas through a fibrous packing material.

20. A method of conserving the refrigeration value of boil-off gas in a double-walled cryogenic storage vessel substantially as described herein with reference to Figs. 1 and 2 of the accompanying drawings.

21. A method of conserving the

refrigeration value of boil-off gas in a double-walled cryogenic storage vessel substantially as described herein with reference to Fig. 3 of the accompanying drawings.

REDDIE & GROSE,
Agents for the Applicants,
6 Bream's Buildings,
London, EC4A 1HN.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1973.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1327944 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

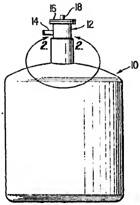

FIG. 1

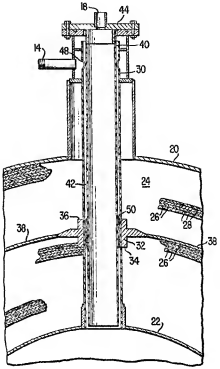

FIG. 2

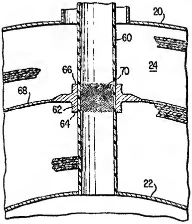

FIG. 3